ATMOSPHERIC METHANE REMOVAL BY METHANE-OXIDIZING BACTERIA IMMOBILIZED ON POROUS BUILDING MATERIALS

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ABSTRACT

Biological treatment using Methane Oxidizing Bacteria (MOB) immobilized on carrier materials is considered as the best solution to mitigate methane emission at low concentrations (e.g., in animal houses). The porosity of the support is one of the most important factors for an efficient removal of methane. In animal houses, building materials having a high porosity may provide a niche for MOB. In this study, we evaluated the methane removal capacity of MOB immobilized on porous building materials.

Six different types of building materials and MOB were chosen for the experiments. Building materials were immersed in an MOB liquid culture (2.10^8 cells/ml) and after 24 hours the liquid were separated. The methane removal capacity of MOB was investigated by analyizing the evolution of the methane concentration in the headspace of a closed incubator containing the materials at starting concentrations of ~20 %(v/v) and ~50 ppmv.

MOB immobilized on Maastricht limestone and *Ytong* exhibited higher methane removal rates compared to when immobilized in other materials with *M. parvus* NCIMB 11129^T in Maastricht limestone (0.1 mg CH_4 (m^3air h)$^{-1}$) exhibited the highest rate at ~50 ppmv and *M. trichosporium* NCIMB 11131^T in Maastricht limestone (1451 mg CH_4 (m^3air h)$^{-1}$) at ~20 %(v/v). Both materials exhibited the highest macropores (i.e., pore diameter > 3 μm) volume. Therefore, they were likely to accommodate more bacteria and consequently higher methane removal rate by the MOB. *M. parvus* and *M. trichosporium* were able to remove methane for two months with decreasing activity. From this study it was shown that methane can be efficiently removed from the air by MOB immobilized on building materials.

1. INTRODUCTION

Biological treatment using immobilized Methane Oxidizing Bacteria (MOB) on carrier materials is considered the best solution to mitigate the emission of methane, one of greenhouse gasses, to the atmosphere. The porosity of carrier materials is considered one of the most important factors for a high removal of methane. In animal houses, where methane is emitted from the digestive system of ruminants, building structure comprised of materials having a high porosity may provide a niche for MOB. The objective of this study is to evaluate the methane removal capacity of MOB immobilized on porous building materials

2. MATERIALS

Ytong, Maastricht and Euville limestone were the selected building materials. Six different MOB were also selected: *Methylomicrobium alcaliphilum* DSM 19304^T, *Methylomicrobium kenyense* DSM 19305^T, *Methylosinus trichosporium* NCIMB 11131^T and *Methylocystis parvus* NCIMB 11129^T, *Methylomonas methanica* 11130^T and an MOB mixed culture. The methane removal capacity of each MOB immobilized in each of the building material was investigated.

3. METHODS

Building material blocks were cut into: 1 cm x 2 cm x 5 cm. Before tested, the porosity of materials was analyzed in triplicate by means of Mercury Intrusion Porosimetry (MIP) method according to Aligizaki, 2006 [1]. Each block was glued on the bottom of a 250 ml schott bottle using epoxy glue and autoclaved. The following procedure was performed under sterile condition except for the mixed cultures. MOB liquid culture (~150 ml) was poured into the schott bottle until the specimen was immersed. The schott bottle was closed and incubated at 28 °C under atmospheric air and at static conditions for 24 hours. The liquid was separated from the specimen afterwards. The schott bottle was sealed with a butyl rubber stopper and screwed with an aperture cap. Experiments were performed to investigate the methane removal capacity of MOB at high (~20% (v/v)) and low (~50 ppmv) methane concentration. Both concentrations were tested to study the potential application of this process (i.e., landfill for high concentration, animal house for low concentration).
Schott bottle containing building material inoculated with bacteria was injected with methane before measurements and incubated at 28 °C under static condition. Gas composition and pressure were measured to calculate the methane concentration over 100 (high concentration) or 200 hours (low concentration) of incubation. Gas composition was measured using a Compact GC (for high concentration) equipped with a Thermal Conductivity Detector and a Trace GC Ultra (for low concentration) equipped with a Flame Ionization Detector. Three types of additional experiments for each building material and methane concentration were performed to confirm the biological nature of the methane removal. These were activity tests using: (1) only building material, (2) sterile medium incorporated building material, and (3) autoclaved bacteria in building material. Each experiment was performed in triplicate.

4. RESULTS

MOB were capable to remove methane from the air when immobilized in each of the building material tested both at high and low concentrations (Table 1). Except *M. kenyense*, MOB exhibited higher methane removal rate in *Ytong* and Maastricht limestone than in Euville limestone at high concentration with *M. trichosporium* in Maastricht limestone being the highest (1451 mg CH_4 (m^3 air $h)^{-1}$). Lower methane removal rates were exhibited by all MOB at low concentration compared to at high concentration. *M. parvus* in Maastricht limestone exhibited the highest methane removal rate (0.1 mg CH_4 (m^3 air $h)^{-1}$ at low concentration. No methane removal could be observed from the control series.

Table 1: Methane removal rates (mg CH_4 (m^3 air $h)^{-1}$) of different MOB in different building materials at high and low concentrations. Bold font indicates the highest rate at each concentration.

	M. alcaliphilum	*M. kenyense*	*M. trichosporium*	*M. parvus*	Mixed culture
High concentration					
Ytong	1040	186	109	782	777
Maastricht limestone	1128	116	**1451**	836	850
Euville limestone	333	128	94	65	79
Low concentration					
Ytong	0.08	0.03	0.01	0.07	0.02
Maastricht limestone	0.05	0.02	0.09	**0.10**	0.03
Euville limestone	0.06	0.02	0.03	0.02	0.06

Among all building materials tested, *Ytong* and Maastricht limestone exhibited the highest macropores volume (i.e., pore with diameter > 3 µm) (red box in Figure 1). When incorporated inside building materials, higher amount of MOB are likely to reside within the material with higher macropores volume. With higher amount of MOB likely to be incorporated inside *Ytong* and Maastricht limestone, higher methane removal rates were exhibited by MOB in these materials (Table 1).

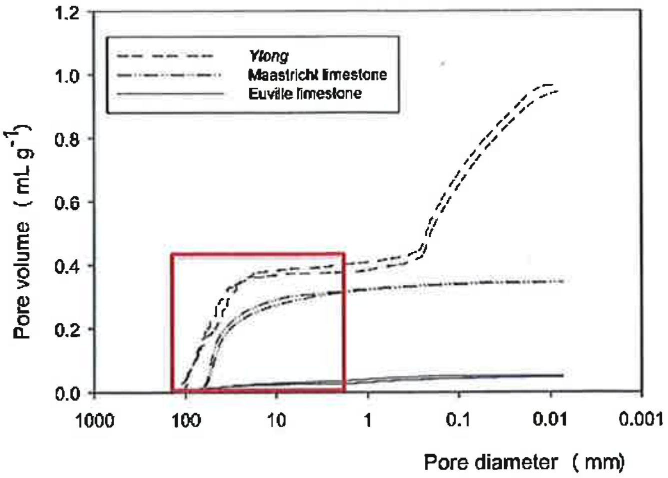

Figure 1: Pore size distribution of building materials from MIP analysis. The box indicates the area in which MOB are likely to reside inside the materials.

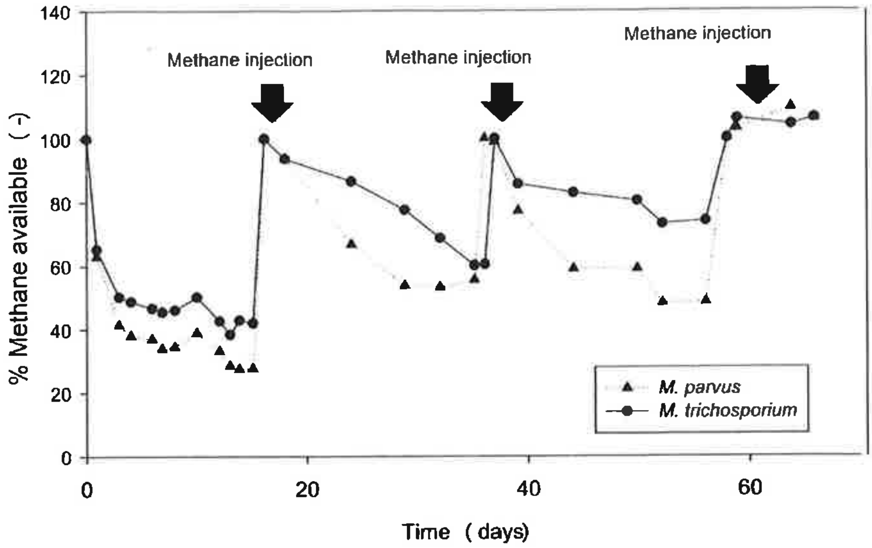

Figure 2: Period of methane removal by *M. trichosporium* and *M. parvus* in Maastricht limestone at low concentration

M. trichosporium and *M. parvus* could remove methane for approximately two months before they lost their methane removal capacity (Figure 2). After initial methane removal, additional methane was injected to the incubator. Both MOB could remove methane with decreasing rate after the first and second methane addition. After the third methane addition, no methane removal could be observed.

5. CONCLUSIONS

MOB could remove methane when immobilized on building materials at both high (~20 % (v/v)) and low (~50 ppmv) concentrations. MOB had higher methane removal when incorporated in building material with higher proportion of macropores volume. *M. trichosporium* and *M. parvus* could maintain their methane removal capacity for approximately two months with decreasing activity

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